



Biological Clocks

MANORAMA JAFA

PUBLICATIONS DIVISION

ACC NO

1401

THE INDIAN INSTITUTE OF WORLD CULTURE
6, SHRI B P WADIA ROAD,
BANGALORE-560 004.

THE
INDIAN
INSTITUTE OF
WORLD CULTURE
BANGALORE
PHONE : 6678581

THE INDIAN INSTITUTE OF WORLD CULTURE

6, Shri B.P. Wadia Road, Basavanagudi, Bangalore-4

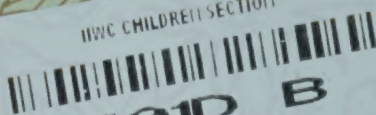
Estd. : 1945

Telephone : 6678581

Kindly return this book not later than the date
given below.

Thank you

IIWC CHILDREN'S SECTION



1401D B

ACC NO

1401

THE INDIAN INSTITUTE OF WORLD CULTURE
6, SHRI B P WADIA ROAD,
BANGALORE-560 004.



N. Rajappa
D.B.
J

THE INDIAN INSTITUTE OF WORLD CULTURE
6, SHRI B P WADIA ROAD,
BANGALORE-560 004.

BIOLOGICAL CLOCKS

Manorama Jafa

Illustrations by
Jivan Adelja

Publications Division
Ministry of Information and Broadcasting
Government of India

1401

December 1979 (Pausa 1901)

©

Price: Rs. 9.25

PUBLISHED BY THE DIRECTOR PUBLICATIONS DIVISION
MINISTRY OF INFORMATION AND BROADCASTING
GOVERNMENT OF INDIA PATIALA HOUSE NEW DELHI-110001

Sales Emporia ● Publications Division

Super Bazar Connaught Circus New Delhi-110001

Commerce House Currimbhoy Road Ballard Pier Bombay-400038

8 Esplanade East Calcutta-700001

Shastri Bhavan 35 Haddows Road Madras-600006

Bihar State Co-operative Bank Building Ashoka Rajpath Patna-800004

Press Road Trivandrum

Printed by Indraprastha Press (CBT) Nehru House New Delhi-110002

Preface

From childhood I had been interested in the strange behaviour of plants and animals. Touching the 'touch me not' plant used to be such an attraction that whenever I got a chance I spent quite some time to watch the behaviour of the leaves. What a fascinating sight! Just touch the leaves and all the leaves will fold as if they are dead. After some time they would again open up and stay erect.

I recall once taking a stroll with my mother in the garden. It was a moonlit night in summer and fragrance of a white flower attracted me. As soon as I reached my hand to pick the flower, mother held my hand. "Do not disturb the plant. It is sleeping", she said. Since then I never touch the plants at night. Years have passed since this incident happened but the impression has remained. That was my first encounter with the rhythm patterns of the plants.

In our garden we had sunflower plants also. Large flowers with yellow petals and chocolate centre! What a beautiful sight! And sunflowers surprised me with their unusual behaviour. They changed their position with the changing direction of the sun. As the sun goes from east to west, the flowers also shift their face position as if following the sun. The movement of sunflowers was another discovery.

In the courtyard of my home, a pair of wagtails came every winter. I fed them with grain and also placed some water for them. They disappeared around March and returned again at the end of October.

Migration

After dark, moles and mice were regular visitors in the kitchen and as children we set the traps for them in the evening. Every morning one or two were trapped and despite this their behaviour pattern did not change. These observations made me interested to know more about strange behaviour of plants and animals.

Years passed. One day, in 1968 I met Dr. Gir Raj Singh Sirohi (Indian Agricultural Research Institute, New Delhi) and learnt about his work on 'biological clock' and also how he had gone to the South Pole for his scientific experiments. His story fascinated me and I wrote a book *100 Days in Antarctica*, which has recently been published.

My curiosity about the 'biological clock' got deeper and I itched to know more. I observed even the daily behaviour of human beings. How an old lady, in the neighbouring house, used to get up exactly at four o'clock in the morning without the help of any watch or alarm. Then I learnt how important this 'biological clock' is for all living beings.

The working of the biological clock is more precise in birds, animals and plants. Since we human beings rely more on artificial devices and keep fighting with our natural 'biological rhythms', the clock in our system has become less sensitive. The animals, plants and birds still have their natural device, the 'biological clock', intact which guides them in their behaviour at different times precisely and appropriately, as this is important for their survival.

I am particularly thankful to Dr. Sirohi who has generously spared his time for consultation. I also acknowledge my sincere thanks to Dr. M.K. Chandrasekharan of Madurai University who, besides giving me a lot of information, has let me use some of his observations in this book.

I am indebted to Mr. K. Shankar Pillai, the famous

cartoonist, who has pioneered the development of good literature for children in India. He has always encouraged me to write books for children.

I dedicate this book to my parents and specially to my mother who had once asked me not to disturb the plants at night and had aroused my curiosity towards the behaviour of all living beings.

New Delhi, August 1979

Manorama Jafa

Contents

1	Biological Clock: an infant scientific idea	1
2	Timing Mechanism: some fascinating examples in nature	7
3	The Scientific Pursuit: the idea of the biological clock	13
4	Biological Clock: in the service of mankind	21

1

Biological Clock : an infant scientific idea

It was a sunny afternoon many many years ago, when Alexander the Great camped near a jungle in the north-west of India. After the troops had settled down, Androsthenes, a commander in Alexander's army, changed his uniform and asked his chief's permission to have some fresh air in the wilderness. The chief was taken by surprise.

"But you must be tired, Androsthene's."

"Oh, no sir..." and before Androsthene could finish, the chief added, "I know, I know. You may be wanting to look at some plants."

Androsthene saluted the chief and walked away.

Androsthene loved to look at different kinds of plants and study their foliage, their buds and flowers. He now walked straight to the woods. He knew many of the plants but some of these he had never seen before. He was fascinated by the shapes of their leaves and their lush green colour. He observed that as the darkness fell, the leaves of the tamarind tree did not remain erect but were drooping. As he walked back to his tent, he was still thinking about the drooping leaves. For a moment he thought he was mistaken and decided to go back and look at the plant again. Of course, the leaves were drooping.



The following morning he again rushed out to look at the plants and to his surprise the tamarind leaves were open and erect. And in the evening the leaves were drooping again. He observed this pattern of leaf movement for several days and kept a note in a handy diary. This was perhaps the first ever record of the timing rhythm in plants.

For long people have observed the behaviour pattern of plants, birds, worms and animals and discovered many interesting examples of a timing mechanism or rhythm in nature. With the first rain in summer, frogs and toads appear all over the place. In winter they disappear and go in hibernation, and are not seen until the rains come. It has also been observed that frogs appear on about the same day year after year, on the same stretch of water. They are also known to hop to the same pond year after year, generation after generation and to breed almost at the consistent time. Not only that, at the set time of the year they come out and follow the traditional routes. Once, when a main road was built across one of these migration routes, hundreds of dead frogs were seen killed by the night traffic.

Similar rhythms are also common in the behaviour of plants and animals. Scientists have been astonished by the uncanny sense of time exhibited by birds, bees, worms and plants in their day-to-day behaviour. An internal timing mechanism guides birds to know exactly when to migrate to the warmer regions to avoid extreme cold of the north. Owls, rats and cockroaches sleep during the day and are active at night, whereas other creatures commonly restrict their activity to daylight hours. Bats fly out evening after evening with great precision. Crows, mynahs, squirrels are up at about 6 a.m. and retire at about 6 p.m. even when they are kept into windowless rooms where they cannot see the sunrise or sunset.



In the plant world too similar examples are found. The bean plants fold their leaves during the night and open in the day. Flowers open and close at certain times of the day with surprising accuracy. Morning glory, a common garden creeper, and portulacca flowers bloom in the morning and as the day grows, they lose their fresh looks and by evening they are closed. Next morning, the plant is again full of blooming flowers.

Observing the time of the opening and closing of flowers, Linnaeus, a Swedish naturalist, got a fascinating idea. He constructed a flower clock and by looking at the bloom that was out at a particular time, he knew the time of the day.

The biological functions of the human body too go on uninterrupted like a clock. These rhythms function even when man sleeps or keeps awake, often without his knowledge. The different functions of the human body follow a rhythm or a set pattern over a twenty-four hour period. Thus the temperature of the body, eating and sleeping patterns, breathing, heart beat and chemical activities of the kidneys, liver, digestive system and nervous system—all seem to follow a regular rhythm. Persons travelling by aeroplane over long distance experience disturbance in their sleeping and eating patterns. It takes a few days before the body readjusts itself to the change of the timings. This happens due to disturbance of the normal daily rhythms of the body functions which dislocate not only the sleep but also other functions of the body.

In nature too, things go on according to certain set patterns. The earth rotates on its axis once in twenty-four hours, giving us day and night. The number of hours of daylight every day varies with the seasons and repeats the same pattern year after year. The earth's revolution around the sun gives rise to our seasons. The movement of the moon around



DFP ①

2 - flower

18

DM ①

4. Man

the earth and the earth's revolution around the sun together give us the lunar month and the cycle of tides.

In several parts of the world marked seasonal changes occur in the temperature and humidity. Thus the climatic conditions at certain seasons may even threaten the life of animals and plants. In severe cold weather at higher altitudes life becomes extremely difficult. Similarly, some areas become very dry. Many plants and animals in such areas use the changes in day length as the indicator of the season and their biological clocks influence a change in their behaviour patterns. In plants, the flowering, the beginning and end of the period of dormancy in buds, seed germination and many other processes are thus regulated by an in-built timing mechanism. In animals, the periods of hibernation, migratory restlessness, changes in colour and thickness of the pelt are also similarly regulated. Some of these plants and animal species are active during the long summer days with dormancy coming over when autumn comes. Other organisms are active during shorter days of autumn or winter and remain in an inactive or dormant state during summer, mainly when that season is particularly hot or dry. But the most surprising fact is that when the correct duration of the day-time (or the night-time) arrives, the organism's behaviour pattern, like the flowering in plants, changes abruptly from one seasonal rhythm to another.

Some long-lived plants and animals possess a different rhythm, regulating something like an annual cycle. These annual rhythms of seasons control breeding, wool growth and hibernation among animals. Domestic sheep have an annual cycle of wool production, which increases during the summer months. Sheep kept under experimental conditions of continuous light maintain such cycles. Rodents exhibit cycles of hibernation and activity, often disappearing

and again appearing at precise times of the year. In ground squirrels there is a clear cycle of hibernation, change in body weight and temperature. Their body weight is the maximum when they go into hibernation and the minimum when they 'wake up'.

The bird and animal travellers of our world cover long distances year after year at almost the same time and the same way, which is of course very fantastic. Birds are the greatest of all travellers, but even the spider, crab, tortoise, fish all leave home when the moment is right. Imagine the tiny, exotic humming birds and the lovely, fragile butterflies setting out on a journey hundreds of miles long.

Man's dependence on the clock has grown with the awareness that time is valuable and must be used well. Over the ages, man has developed his own devices for measuring time. He has used the sun-dial, water clock, candle clock, pendulum clock, mechanical and the electronic clock. Today if the clocks of the world stop working, no one would be able to do any work on time. The trains, the aeroplanes, even the radio and television, the entire life will be dislocated. Thus modern life has come to revolve around the clock and all our activities depend on it.

It is amazing that all living things have their own 'built in' clocks, which continue to work by themselves with clock-like precision even when they are kept away from light in constant darkness and at constant temperature. It is not only the everyday life of the plants, birds and animals that is guided by a natural time sense but also their seasonal behaviour. Many research workers all over the world have studied these behaviour patterns and have found that plants and animals have their own biological clocks. This biological clock enables them to measure time and determines the rhythmic pattern in their behaviour.

Until recently these observations were regarded as

only interesting events in the life of plants and animals.

Then Gustav Kramer, a German scientist, who had been studying birds' ability to navigate by the sun, found that a bird might be able to use the sun as a compass and even have a time sense, i.e. a biological clock, which enables it to adjust its course to compensate for the sun's movement across the sky. Ever since, the term 'biological clock' has come into general use.

The 'biological clock concept' led to many new scientific observations. Even the old observations now acquired a new meaning and are now better understood. These observations clearly showed that repetitive activities of plants and animals have rhythms—some occur once in twenty-four hours, others occur every hour, or even every second. In some living beings these rhythms occur every week or every month, in some others it may occur only every seven years, or even every seventeen years.

The idea that all living beings have an in-built biological clock has contributed greatly to the understanding of the life sciences in this country. Before we learn more about the biological clock, let us look at some truly fascinating examples of the timing mechanism in nature.

2

Timing Mechanism: some fascinating examples in nature

Migratory Birds

Bharatpur has the largest bird sanctuary in Asia, full of marshes and trees, and here the migratory birds find a paradise. Once, early in October, I visited the Bharatpur bird sanctuary and was pleasantly surprised that several migratory birds from cold regions had begun to arrive. Here, I saw the Siberian white goose, Siberian white stork, and the Arctic tern. These birds begin their journey in early September and take almost a month to finish up their long journey. They prefer to settle down on trees which are surrounded by water. It is interesting to watch them in the sanctuary. The whole place looks like a den of birds and human beings look like intruders. In early March when the weather starts warming up, these birds are ready for their homeward journey and, following their leaders, they fly towards north. Bird watchers have found that the migratory birds follow the same path and the same timings year after year. Salim Ali, the famous Indian ornithologist, has recorded that a ringed grey wagtail was found to return, presumably from its Himalayan breeding grounds at least 2000 km. distant, to a particular

lawn in Greater Bombay, no bigger than a badminton court, on almost the exact date in September for five years in running. Incoming Orphean warblers ringed in Saurashtra in September one year were retaken in nets at about the same place in the same month, almost to the date, in the following year; in one case even in each of the three successive years.

The most important factor responsible for this set and strange behaviour must be 'self-preservation'. However, even in cold countries not all birds move to southern warmer climates. Penguins stay on the continent of Antarctica. Young Siberian jays adapt themselves to the cold, huddle together for warmth in an early frost in the north of Europe and Arctic region. But these non-migrant birds are more thickly feathered than their migrant kins. And also by fluffing out their plumage and trapping their own body heat, they can further insulate themselves. Thus they do not need to migrate to escape cold. At the same time, if food becomes scarce, they also fly as far as central Europe to seek it.

Monarch Butterflies of North America

Monarch butterflies are widely distributed in the United States and Canada. The Monarch is a beautiful butterfly of chestnut colour. It has black veining on its wings and is three inches across the spread wings, much bigger than our common Indian yellow butterfly. These Monarchs migrate in millions every year and the sight of these exotic migrating butterflies has aroused curiosity and has been widely studied. Early in September, the Monarchs begin to fly south. This movement starts in the most northerly parts of their range, when in twos and threes they set out to fly south. As they do so, small groups join up to form larger and larger groups until there are steady streams



of millions, stretching for long distances. One stream goes down to Pacific coast, the other stream down the eastern U.S.A. even as far as Mexico. The streams of Monarchs cross eastern North America in the direction of Florida and Texas and along the west coast to California. Arriving at the destinations they pass the winter in a state of semi-hibernation on the trees, hanging by the thousand on each tree. Although the same trees are used year after year, it is not the same butterflies that use them but their children and grandchildren.

After a long sleep of a few months, in the month of March the Monarchs become active again and fly back northwards arriving in south Canada about the beginning of June. The return journey from Canada to Florida or South California is well over 3,200 km.

There is a small jungle near San Francisco. This jungle is notable for its butterfly trees where the Monarchs have assembled to hibernate for over sixty years. Their dense masses present a fascinating sight and are a great tourist attraction. Chestnut clouds of butterflies cover the sky and present a picturesque view. The trees on which they settle down

to hibernate are known as butterfly trees. The time of their arrival and after their settling down on trees, both present rare sights. The local authorities take special precaution to preserve this ecology. Anyone throwing a stone at the butterfly trees, disturbing them and harming them in any way can be fined up to 500 dollars.

White Butterflies of East Africa

Dr. Williams one of the great authorities on migratory insects, has given an interesting account of white butterflies on migration in East Africa. His cottage was sited at the top of a raised ground, was in the path of the migrating butterflies. During the course of their flight when they passed by this house, the butterflies began to beat themselves against the wall. Instead of going round the house, however, they retreated, then flew higher, going up the wall and over the roof to maintain their original direction.

Grunions of Southern California

Grunion is a slender silver fish. It rises on the crest of the waves as the high tide recedes in the sea off Southern California in the U.S.A. The fish is washed on to the moist sand and spawns, and then flips back towards the water.

The timing sense of the Grunion is so precise that it comes about fifteen minutes after the high tide, when the water is just a few inches lower. At that moment, the fish lays eggs in the sand above high water. These remain buried in the sand and mature and are ready to hatch in fifteen days when the next high tide arrives. As the waves churn the sand, the baby fish are freed from the egg pods and are ready for their journey into the sea.

The Grunion hunters make it an occasion and hundreds of them come with their buckets to catch the fish. It is quite easy to know when the Grunions will come, but it is amazing how Grunions know exactly the time most suitable for the survival of their young.

Palolo Worms of Fiji

A similar spectacle takes place over the coral reefs near Fiji and Samoa. At about dawn on the first day of the last quarter of the moon in November, the Palolo worms swim to the ocean surface in large numbers. Just before dawn people of Fiji and Samoa bring their boats and canoes directly over the reefs where the worms will rise and scoop them up as much as they wish.

Three-hour Bird of Panama

In Panama, Pileated Tinamou is a fascinating bird species, resembling a tiny ostrich. The bird sings every three hours, day or night. It is so punctual that in Panama it is called a three-hour bird.

Pair of Kites or Temple Birds of Tirukkalukundram

Tirukkalukundram is a hill shrine on the link road between Chingleput and Mahabalipuram in Tamil Nadu. Exactly at twenty-four hour interval two kites arrive at a fixed time everyday, an hour before noon, to be fed by the priests. This unusual behaviour of the two birds is explained by a fascinating legend that the birds are in fact two saints, who take a break at this spot on the flight from Varanasi to Rameshwaram. Scientifically this visit could be explained that these birds have time memory which is guided by their bio-

logical clock and they keep visiting the temple at the fixed hour. However, twenty-four hourly visit by only two birds for generations is still an unexplainable miracle.

Himalayan Birds and the Weather

Mountaineers in the Himalayas generally have to depend on their sherpas' experience to know about favourable weather conditions for climbing. Recently Yuichi Matsuda, a Japanese mountaineer, has discovered that the movements of migratory birds have something to do with the weather. He observed that Siberian cranes migrate for about ten days after the monsoons or in the beginning of October and also that during their migration, weather throughout the Himalayas remained clear and best suited for climbing.

Similar interesting observations have been made by man for a long time. But these were long regarded as only fascinating events of local importance, not as a part of the grand design in nature. Only in recent years scientists began to ask themselves what brings it about, and how. In the 1960s, it came to be widely accepted that an internal clock determines the behaviour pattern in living organisms. In the pages that follow we shall see the nature of the clock and how it effects the behaviour patterns of living beings.

*Butterfly
collecting the nectar
from the flower*



*Honey bee
collecting honey
at the right time*





Sunflower following the sun from east to west



'Touch-me-not' leaves open and normal



'Touch-me-not' leaves drooping after being touched



*'Morning glory'
in bloom
early in the morning*

*Squirrel active
after a period of
hibernation*



*Mouse is active
at night*



*Priest feeding
the kites at the
Tirukkalikunram Temple*



3

The Scientific Pursuit: the idea of the biological clock

The daily leaf movements in plants were studied by Androstheneas over 2000 years ago and are among the earliest observations of the twenty-four hour rhythm. In the eighteenth century French astronomer, De Mairan, also observed these movements and moved one step further. He transferred his experimental plants to a dark cellar to see how far the darkness affects the behaviour of plants. To his great astonishment he found that the leaf movements continued in the total darkness the same way as in the daylight. This experiment led him to conclude that the leaf movement was guided by an internal clock-like mechanism.

In the fascinating world of nature, the biological clock enables plants and animals to partition or divide their time and adapt their behaviour pattern to suit their best advantage. Thus, quite a few animals move about in search of food only when it is totally dark, while others use the same food resource during the day. This behaviour pattern reduces direct competition between them.

The biological clock also enables the animal or plant to 'prepare' and 'anticipate' a situation. The external stimuli like the daylight and temperature

also affect their behaviour in many ways but the biological clock enables them to remain wholly self-reliant. Thus, the mouse does not have to depend for being woken up abruptly by the approaching darkness. The biological clock slowly prepares him for the waking up process. The same way, the honey bee is also guided by its 'clock' to know or remember when exactly the flowers will have nectar for them. Such rhythms are like 'ringing a bell' and telling the insects, plants and animals that it was time for them to follow a particular behaviour. This is like a clock alarm, signalling the occurrence of an event at fixed intervals of time.

Over the years, most of the scientists favour the view that the timing mechanism in plants is located within the living organism. Also, for a long time many scientists have regarded the timing patterns in plants and animals as wholly guided by the in-built biological clock, though they recognise that some external factors, such as daylight, temperature, seasons also influence the behaviour patterns. However, other scientists consider the timing patterns to be mainly influenced by external factors. The main curiosity now revolves on how far the environment plays a part in the behaviour patterns.

The yearly migration of birds from the cold regions of north to the warmer regions of south in winter provides a good example of the timing sense in the birds. What prompts birds to start their migration at approximately the same time every year? The scientists have been baffled to find that the timing sense of the birds is so precise. Their observations led them to believe that one of the factors which seems to start these changes in their behaviour is light. When the light decreases in autumn, the birds prepare for their southward journey and with the increase of light in spring they again start their homeward journey. Still

it is a mystery that when the right day comes, the birds not thinking how and why, leave for their distant goal. How they find out the exact time, no one understood for a long time.

The scientists knew that there was some special sense of timing which guided them to travel in a particular direction. Some scientists thought that it could be guided by some external factors. This group of scientists stated that birds in the cold northern regions start planning their journey in early autumn when the light of the sun starts thinning. They start flocking together and then fly southwards. The annual behaviour of birds connected with the sun's diminishing light was an interesting and strong point. But scientists argued that though the sunlight and temperature certainly help birds to move southwards, this alone is not enough and did not fully explain the birds' behaviour concerning their sense of direction.

It is now generally accepted that sense of timing and sense of direction of birds' navigation are closely associated phenomena. A number of factors besides light may play part in the birds' timely flight in a definite direction.

The curiosity to know about the mysterious journey of the birds prompted the early bird watchers to follow these birds and find out when and where exactly they moved in winter and how they appeared again. They followed the birds with the aid of binoculars, telescope, radar, aircraft and other tracking devices. Many of them trapped the birds in nets and dyed them before letting them free again.

Of all the ways men have devised for following birds, the most effective is the process of ringing, which picks out a single bird at two specific moments. First, when the ring is snapped around the bird's shank and second again when it is once more recovered alive or dead. These light aluminium or



coloured plastic rings carry the name of the place where they are ringed and the date when they are ringed. This method has proved very successful and scientists have been able to record many startling facts about the behaviour of birds, like the time of their departure and return, direction of flight and the distances they cover during these migrations.

Once I stood in an open corner of the Delhi zoo in the month of October when a white bird with a long beak settled down close to me. A bird watcher quickly spotted it and I heard him saying, "A bird from Siberia". I rushed to the gentleman and asked, "But how do you know?" He explained that a few days ago a similar bird had been captured in Delhi. It had a ring with Russian lettering on its shank. The bird had probably migrated from Siberia and must have been one of the many thousands that flock to northern India during winter months which both the Soviet scientists and the Bombay Natural History Society keep track of.

It is really strange that the birds can follow their invisible paths so precisely that from time to time it has been speculated that they certainly possess a special sense unknown to man. At one time they were thought to have kinaesthetic sense, that is, the sensation of position and movement of parts of the body by which they could form patterns of their route through pressure on the inner ear. Another idea was that birds navigate through responses to the earth's magnetic field, perhaps even to its rotational effects. But none of these ideas stood the test of experiment. More convincing is the evidence that a bird's eyes and vision play the primary role in its sense of direction and position. And if the bird locates itself by means of visual landmarks like river valleys or mountains, it is only a step further to the idea advanced by Gustav Kramer and others that a bird might be able to use

the sun as a compass and even have a time sense, that is, a biological clock, which enables it to adjust its course to compensate for the sun's movement across the sky.

There are also other types of biological time responses which enable an organism to be 'aware' of the time at most periods of the daily cycle. This 'biological clock' guides honey bees to go out to pick up nectar from the flowers at the right time of the day at intervals of twenty-four hours. The honey bees can also 'learn' to visit several different sources of nectar at different times of the day. Guided by their biological clock, several animals, bees and birds can even have time memory and maintain a fixed direction with the help of the sun's azimuth, and even taking into consideration sun's movement through the sky. In these types of biological time responses the animals or the insects appear to be aware of the passage of time, just like our watches tell us the time.

Honey bees have been known to possess 'time memory' since the turn of the century. Auguste Forel, a Swiss naturalist, made an interesting observation in 1906. He loved to have his breakfast on the terrace of his home. He noted that every morning the honey bees came to his table to feed on the jam and jellies. Their time of arrival was so precise that Forel kept a watch on them and began to time them with his watch. The bees arrived at about the same time every morning, even if there was no jam or jellies on the table. One day when Forel ate his breakfast inside the house and not on the terrace, the bees came on the terrace at their usual time. He had first thought that probably their sense of smell had helped them to make their scheduled journey at the breakfast time. But now Forel concluded that bees had a 'memory for time' guided by the biological clock and thus were able to observe the time schedule.

A few years later, a German scientist, Von Buttel Reepen, also began to study the behaviour pattern of the bees. He liked to take a walk through buckwheat fields. He observed that the bees stayed in the field until about the middle of the morning and left when the buckwheat flowers stopped their flow of nectar. Von Buttel Reepen found the flowers as fragrant in the afternoon as they were in the morning. But the bees did not come back in the afternoon which showed that the fragrance did not affect the behaviour of the bees.

Von Buttel Reepen suggested that the bees had an actual time sense and were guided by an internal clock. He gave a new word *Zeitgedachtnis* (time sense) to express his idea, which is now commonly used both in German and English languages.

Probably, the most outstanding work on biological clocks has been done by Erwin Bunning, who is the acknowledged father of the 'clock' idea. After years of painstaking research, in 1936 Bunning put forward his conclusions

—that plants have an in-built and nearly automatic rhythm which repeats itself at about twenty-four hours interval.

—and the organisms use these rhythms to measure time.

At that time these ideas were just too fantastic and caused great stir among the scientists. As it so often happens in the early stages of a new scientific idea, enough experimental work did not exist to support the 'clock' idea at that time. Over the years scientists have done a lot of experimental work and the concept of the biological clock has been accepted widely.

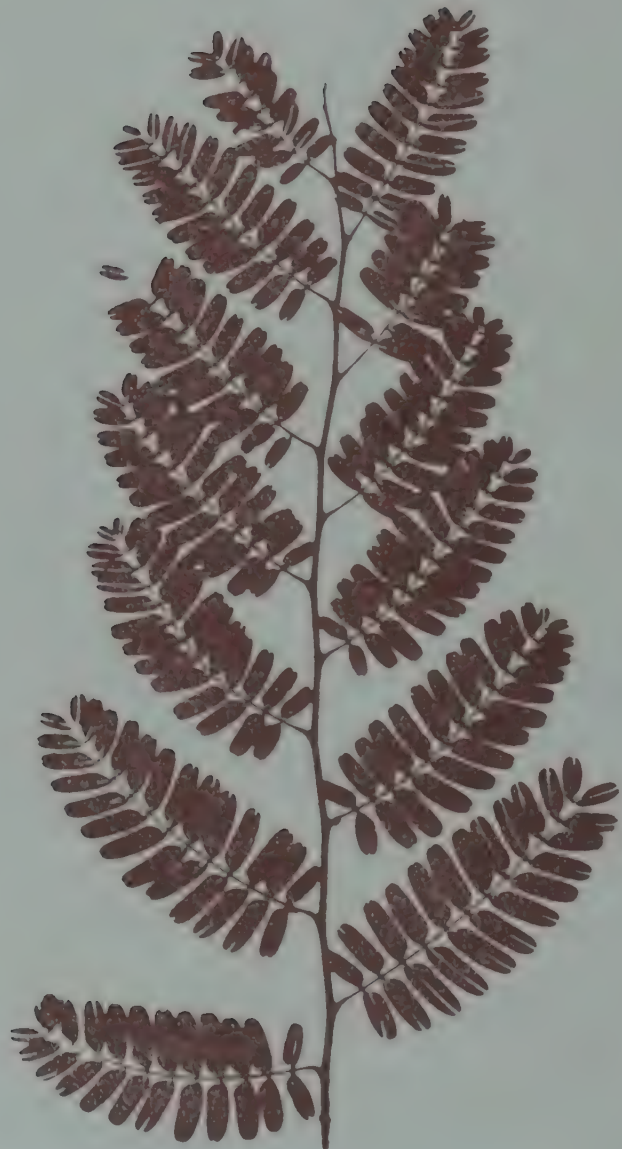
The one way to know more about the biological

clock would be to watch the behaviour of some plants and animals whose behaviour is well known to man, in a distant solar orbit where these could be kept away from the effect of light, temperature, rotation of the earth or any other external influences which might be responsible for the rhythmic behaviour patterns. Such an experiment has not been possible so far. But in 1960 an Indian scientist, G.S. Sirohi, together with Prof. K.C. Hamner (USA) and T. Hoshizaki (USA) went over to the Antarctica with some plants and animals. Sirohi carried out experiments at the South Pole and watched a number of rhythmic behaviour patterns. He placed hamsters, bean plants, fruit flies and fungi on a specially designed turn-table. This turn-table rotated either from right to left or from left to right to counter the minimal rotation of the earth at the pole. The organisms were kept in constant darkness and at constant temperature in some of the experiments.

The plants and animals followed their usual routine even at the pole and there was no influence of earth's rotation. The hamsters went off to sleep at about six in the morning and woke up at about six in the evening. They kept their twelve hourly schedule. After sleep they started running about in search of food even though there was no food to be found. The bean plants opened their leaves in the morning and closed them in the evening. The fruit flies hatched every twenty-four hours in the early hours of the day. The fungi which could be observed on petri dishes showed light and dark rings of growth every twenty-four hours. The rotation of earth did not affect their behaviour patterns concerning time sense.

The idea of 'biological clock' has enabled scientists to understand better many natural phenomena in the lives of plants, animals and even human beings. As we shall see in the next chapter, this knowledge is now

finding varied applications in scientific laboratories around the world.



Biological Clock: in the service of mankind

For years, the timing mechanism in plants and animals has been observed, but only about twenty years ago the concept of the biological clock came to be widely accepted. As we have noted earlier, the idea of the biological clock has contributed greatly to the understanding of the life sciences and has begun to be used for our benefit.

In medical science the basic understanding of the biological clock has enabled scientists to find a variety of applications. For example, an elderly lady in New York City was unable to sleep until about three in the morning. After going to sleep at such a late hour, she did not get enough rest before going to her office. As a student also she had always found it difficult to keep awake in the classroom without taking a lot of coffee. No amount of drugs or other treatment could help her. Recently, she has been cured, not by a drug but by resetting her biological clock. It was discovered that her internal clock was totally out of harmony with most of us and she was unable to keep the same schedule as we do. Recognising her real trouble, the doctor suggested to her that she may begin to go to sleep at 3 a.m. on the first day, then shift the bedtime to 6 a.m. on the second day. She was advised to shift her bedtime by three

hours every day in the same manner. This experiment worked on the woman magically. In about a week she had worked around the clock to a reasonable bedtime. For the first time in years she did not have to depend on sleeping pills and was able to get a good night's rest. By shifting the bedtime, the doctors helped her to read just her biological clock.

Erwin Bunning has noted that in the human body there is a possible relationship between the rhythms of stomach and liver. If these rhythms are disturbed, this can cause gastric ulcers. Disturbance in the relationship of other bodily rhythms can result in different diseases. Experimenting with cockroaches, Harker had found that by implanting the ganglion (a part of the body of cockroach) into an insect which had a clock shifted by twelve hours (as part of the experiment) caused the formation of tumours. Physicians have also noted disturbances which may occur when people work day and night shifts. These observations have led to better understanding of the cause of different ailments.

In agriculture, the concept of the biological clock has been very beneficial to mankind. It is well known that flowering in crop plants depends on the day length and temperature. In crop plants like wheat and rice better understanding of the response of plants to day length and temperature has been used for producing better varieties of wheat and other food crops. New varieties have been produced which suit different climatic conditions. Using the knowledge about available day length and temperature in different seasons, food crops have been developed which can be grown in those seasons.

It has become possible to affect a change in a variety of cotton which was suitable for growing in southern India. This variety can now be grown in Delhi. Many varieties of crop plant seeds have been

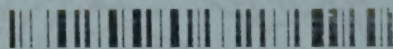


developed which can be grown in different climatic regions of India. Also, in order to take best advantage of soil and climate in a particular region, special seed varieties suitable for that region have also been developed.

The present knowledge about the biological clock is still limited. It is known that it is regulated internally and is not affected by changes in the environment. But no one knows precisely where the clock is located in the organism and what keeps it ticking. With better understanding about the working of the biological clock in the years to come, many more interesting possibilities will be explored to use the knowledge in the service of mankind.

1401

HWC CHILDREN SECTION



1401D B





PUBLICATIONS DIVISION
MINISTRY OF INFORMATION AND BROADCASTING
GOVERNMENT OF INDIA